# SIGMA XI

## HALF CENTURY RECORD AND HISTORY

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# THE INTEGRATED ACTION OF THE ORGANISM EXEMPLIFIED BY STUDIES ON ANOXEMIA*

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I. Analysis and synthesis in physiology.
II. Psychophysiologic relationship.
III. The influence of oxygen deficiency and of carbon dioxid on the cortex of the brain.
IV. The influence of oxygen deficiency and of carbon dioxid on the brain stem.
V. Carbon dioxid as an antagonist to the effects of oxygen deficiency on the brain.
VI. Handwriting and memory.
VII. The mechanism by which carbon dioxid offsets the effects of oxygen deficiency.
VIII. Circulation and posture.
IX. Circulation and respiration.
X. The vasomotor center.
XI. Temperature regulation.
XII. Critical remarks.

I. The method of physiology, like that of any other natural science, is analytic. It is the aim of physiologic research to establish causal relationship between certain factors and certain physiologic events. The study of these relationships makes it possible to predict the course of physiologic processes in a way similar to that in which it is possible to predict the course of chemical reactions in the test tube. Let us assume, for a moment, that the goal of such analytic research was reached and that we had, for instance, a complete understanding of the various physiologic reactions taking place during muscular contraction and relaxation. Unquestionably, such a result would be of greatest importance for the understanding of any living cell, since, in spite of the great specialization which has taken place during phylogenetic and ontogenetic development, each cell has certain characteristics in common with other cells. But even such a result which probably will forever remain an unattained goal of physiologic research would not give us an understanding of the organism as a whole because it neglects the fact that the organism is a system and cannot be understood even by the most complete analysis of each of its parts. The supplementary research is the "synthetic description" (Jordan, 1929[1]) which shows the inter-

* Read at a meeting of the College of Medicine of the University of Illinois chapter of Sigma Xi, December 2, 1936.

relationship of the various organ systems in the body. It is this part of physiologic research which is of greatest importance to the medical student and to the physician, and the results of such investigations may be illustrated on the problem of anoxemia.

It is known, from numerous investigations, that under the conditions of oxygen deficiency a great many reactions take place in the animal and human organism which may be considered to be an adjustment reaction of the organism to the altered conditions. The contraction of the spleen delivers more red blood corpuscles to the circulatory system, the increased respiration increases the oxygen tension in the alveolar air and offsets, thereby, the lowered oxygen tension in the inhaled air to a certain extent. Similar adjustments improving the oxygenation of the tissues may be seen in the facts that the heart rate and the minute volume of the heart are increased, that the circulation time of the blood is shortened, that the blood-pressure rises due partially to the effect of increased secretion of adrenalin, and that the temperature of the body falls. The latter effect, established particularly in small laboratory animals, tends to decrease the metabolic activities of the body, whereas the other reactions tend to increase the amount of oxygen delivered to the tissues in spite of the lowered oxygen tension in the inspired air.

This type of research which will be discussed in greater detail in the second part of this lecture unquestionably enhances our understanding of the organism as a biological system. It shows the intricate manner in which the various organ systems of the body contribute to the maintenance of the most important physiologic functions even under adversary conditions.

II. When we deal with the human so-called "psychic" phenomena which play such an important part in the behavior of the organism must be taken into account. It may be said that a vast problem requiring the application of the synthetic point of view is the problem of the interrelationship of psychic and physiologic phenomena. A fuller understanding of the human organism as a biologic system might be obtained if it were possible to tear down the borders existing between Psychology and Physiology and to show by quantitative measurements that alterations in any physiologic conditions leading to changes in the physiologic functions of the central nervous system and particularly of the cortex alter "psychic" phenomena in a similar fashion.

It is the purpose of this paper to illustrate the principle of synthetic or interpretative physiology in these two directions:

1. By investigating the psycho-physiologic relationship under various experimental conditions.

2. By studying the changes occuring in various organ systems under the same conditions in order to arrive at an understanding of the adjustment mechanism of the body.

Since oxygen is indispensable for all tissues and since the cortex of the brain is more sensitive to oxygen lack than any other organ of the body, it was thought that a study of the effect of oxygen deficiency and some related factors may be appropriate to the elucidation of the problems stated above.

III. Systematic investigations were carried out in which the influence of oxygen deficiency, excess of carbon dioxid, and voluntary heavy breathing (hyperpnea) were studied in relation to various sensory functions, motor coordination, psychic processes, and subcortical reflexes. As to sensory functions which are mediated by the cortex, it was found that auditory acuity[2] and visual intensity discrimination[3] were greatly decreased under all three conditions. Similar results were obtained with respect to visual after-images.[4] Various psychic processes, such as formation of associations, the cancellation of a number (Bourdon's test), the addition of two digits (Kraepelin's test), were investigated with respect to the effects of the three factors mentioned above, and here it was found again that under all three conditions the psychic processes are influenced in a similar fashion.[5] There were only quantitative differences, the changes produced by oxygen deficiency being most severe. It is interesting to note that the type of response in the association test became more individual, that perseverations and finally dissociations devoid of any sense appeared.[6] The time necessary to carry out the Kraepelin and Bourdon tests was greatly lengthened in well-trained individuals. All the phenomena were, in most cases, more or less immediately reversible upon readmission of air.

IV. In contradistinction to these results it was found that physiologic processes involving the lower parts of the brain (brain stem) and not the cortex, showed a different reaction. Investigations of the vestibular nystagmus produced in man by caloric stimulation[7] and in rabbits by galvanic stimulation of the internal ear[8] indicated that under the influence of oxygen deficiency and carbon dioxid excess the number of nystagmic movements* decreased, whereas under the influence of hyperpnea an increase in this reaction was observed. In view of the fact that spinal reflexes also show an increased reaction under hyperpnea and a decreased reaction under carbon dioxid excess and oxygen deficiency, it may be stated that:

1. Cortical reactions show a different behavior from reactions involving other parts of the central nervous system.
2. Psychic phenomena react in regard to oxygen deficiency, carbon dioxid excess and hyperpnea similarly as do ordinary physiologic cortical processes.

These investigations seem to indicate that *the psychic processes are cortical phenomena which depend on and are modified by the same physiologic factors which influence ordinary physiologic processes.*

Since we know that hyperpnea is accompanied by a cerebral vasoconstriction,[9, 10] and, since the cortex in the brain is extremely sensitive to oxygen deficiency, it is very probable that the similarity in the effects of hyperpnea and oxygen deficiency on the cortex are due to the fact that the vasoconstriction produces symptoms of anoxemia in the cortex, whereas in the brain stem and spinal cord which are less sensitive to oxygen deficiency, the effect of the

* Stimulation of the vestibular nerve in the internal ear either by cold or warm water (caloric stimulation) or by a galvanic current (galvanic stimulation) leads to jerky eye movements (nystagmus) which are accompanied by vertigo.

increased alkalinity which increases the excitability of the nervous tissue supervenes.

In view of the fundamental importance of the problem involved it was thought desirable to find out whether it is possible to offset the effects of anoxemia by physiologic means and whether such effects could be obtained under similar quantitative conditions for physiologic and psychic processes.

V. The second problem was to elucidate the mechanism by which such a factor might offset the effects of anoxemia.

Henderson and collaborators[11] recently observed, on Pike's Peak, that administration of carbon dioxid may improve the conditions of persons suffering from mountain sickness. Observations of Mosso (1898)[12] are in agreement with these findings. This made it not improbable that carbon dioxid in proper concentration might offset the effects of anoxemia. For this reason, investigations were carried out to compare the effects of a given oxygen deficient gas mixture on various physiologic and psychic reactions with those obtained with a mixture of the same oxygen concentration plus 3 percent carbon dioxid.

In control experiments it was found that 3 percent carbon dioxid in air had no effect whatever on any of the reactions studied during the duration of our experiments. If, however, it was combined with an oxygen deficient gas mixture the results were striking. (Fig. 1.) The decrease in visual intensity

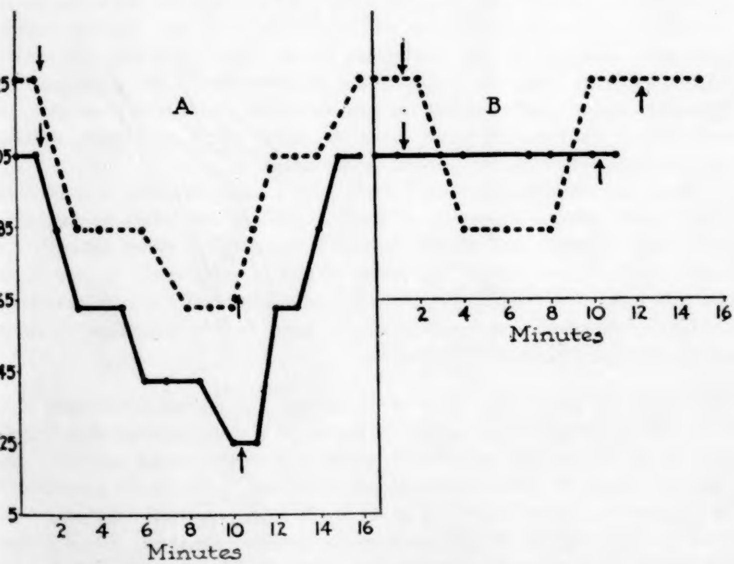


FIG. 1. Ordinate: Reciprocals of the threshold for visual intensity discrimination. Abscissa: Time in minutes. In the figure 1A and 1B, $8\frac{1}{2}$ $O_2$ and $8\frac{1}{2}$ $O_2 + 3$ percent $CO_2$, respectively, were inhaled between the two arrows by two different subjects.

discrimination which results from breathing 8 or 8½ percent oxygen for seven to ten minutes was either completely prevented when 3 percent carbon dioxid was inhaled at the same time, or only a slight decrease in visual intensity discrimination was observed, which was completely compensated for in the time during which the subject inhaled the oxygen deficient gas mixture.[13] The results of experiments on psychic processes were similar. The addition of two digits and the cancellation of a number were carried out without any delay in the oxygen deficient mixture when 3 percent carbon dioxid was inhaled simultaneously, whereas, as mentioned above, these reactions were greatly slowed up under conditions of anoxemia. The type of association remained normal when 3 percent carbon dioxid was inhaled in spite of the low oxygen breathed at the same time.[14]

VI. Most striking were the results in regard to handwriting and memory. Under the influence of anoxemia the handwriting changed greatly. The letters became larger, more clumsy, lost their individual characteristics, and misspelling of the crudest sort occurred. Finally a state of complete illegibility was reached. Even in these severe cases the analogous experiment carried out for the same length of time under the same conditions except for the addition of 3 percent carbon dioxid allowed the handwriting to remain normal. (Figs. 2A and 2B.) Memory tests showed that under conditions of oxygen deficiency the memory functions were severely affected, whereas under similar conditions but in the presence of 3 percent carbon dioxid memory was practically unaltered. Further investigations dealt with the galvanic nystagmus in the rabbit,[8] and with the pupillary dilation resulting from stimulation of the sciatic nerve.[15] Both reactions were depressed under conditions of oxygen deficiency and both reactions were preserved at their normal nevel when the same degree of oxygen deficiency was used and 3 to 4 percent carbon dioxid added.

These experiments show conclusively that a small concentration of carbon dioxid in the inhaled air, which in itself is without any effect on the various physiologic functions and psychic processes investigated, either prevents completely or diminishes greatly the severe effects of anoxemia. It may be said that this antagonistic action of carbon dioxid holds equally true for subcortical and cortical processes and furnishes another proof for the dependence of psychic processes on definite physiologic factors.

VII. Since the great importance of the oxygen for normal functioning of the brain, and particularly of the cortex, is known, it is to be expected that improvement in the cortical and subcortical reactions observed during anoxemia when 3 percent carbon dioxid is inhaled at the same time is due to the restoration of the oxygenation of the brain. This makes it highly probable that one major factor involved must be the alteration in the circulatory system. Blood-pressure experiments in man show, however, very little significant changes under such degrees of anoxemia, which produce marked alterations in cortical functions.[2] It was, therefore, thought desirable to investigate the circulatory system under a certain stress in the human.

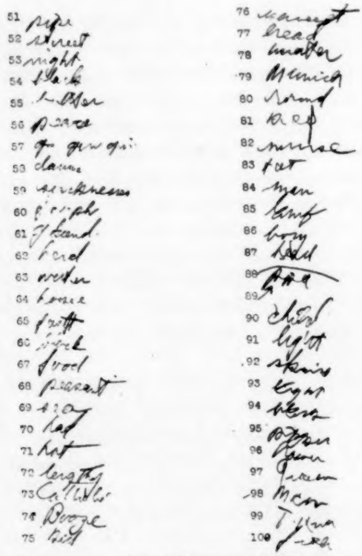


FIG. 2A. The influence of 8½ $O_2$.

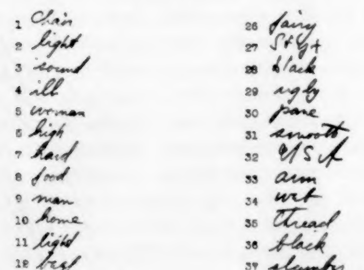


FIG. 2B. The influence of 8½ $O_2$ + 3% $CO_2$.

FIGS. 2A and 2B. Writing in an association test.

VIII. Experiments were carried out on humans in the standing position, and here it was shown that after a slight initial rise the systolic blood-pressure began to fall, and continue to do so until the difference between systolic and diastolic pressure was very small and the subject was near fainting.[16] This typical course of the systolic blood-pressure was greatly altered when the experimental subject inhaled 3 percent carbon dioxid but was subjected to the same degree of anoxemia as before. Now it was seen that the blood-pressure remained either unchanged or slightly elevated to the end of the experiments. Since these typical differences between anoxemia experiments with and without carbon dioxid were not observed when the experimental subject was in a reclining position, it is assumed that the vascular reflexes which originate in the carotid sinus and maintain the normal blood-pressure are weakened under the conditions of anoxemia but are restored to normality in the presence of 3 to 4 percent carbon dioxid.

The great differences in the reaction to oxygen deficiency of the blood-pressure in erect posture and in reclining position are made understandably by the assumption that the carotid sinus reflexes† are weakened in anoxemia. Experiments on dogs are under way to test the hypothesis. The specific differences in the blood-pressure reaction observed in experiments on oxygen deficiency with and without 3 percent carbon dioxid require further explanation.

IX. During anoxemia the respiratory rate and the respiratory volume is increased. That means that carbon dioxid is blown off and the carbon dioxid concentration of the blood is diminished. Such a diminution must occur to a lesser degree or may be prevented when 3 percent carbon dioxid is inhaled at the same time. It may, therefore, be said that during anoxemia (in the absence of 3 percent carbon dioxid) the organism is in a state of carbon dioxid deficiency (acapnia) and that this may be the significant factor accounting for the differences in blood-pressure seen in erect posture under the two conditions. However, a voluntary hyperpnea of a degree similar to that observed during anoxemia does not alter the blood picture significantly. It may be therefore said that acapnea has a much more severe effect under the conditions of anoxemia than when the blood is normally oxygenated.

X. Since the blood-pressure decreases more under anoxemia for a given degree of acapnia than when the blood is fully oxygenated, it was thought possible that an excess of carbon dioxid is more potent under anoxemia than under control conditions. This question was studied in anesthetized dogs in which the effect of carbon dioxid at varying degrees of oxygen deficiency was investigated in regard to the blood-pressure recorded in the carotid artery. Here it was found[17] that small carbon dioxid concentrations (3 to 4 percent) which when inhaled with air did not alter the systolic blood pressure in the dog became effective under conditions of anoxemia. The rise in blood-pressure resulting from anoxemia was much greater when 3 or 4 percent carbon dioxid was inhaled than in their absence. We have then the very interesting situation that

† The carotid sinus at the junction of the external and internal carotid artery in the neck contains sense organs which play an important part in the regulation of blood-pressure respiration.

carbon dioxid antagonizes the effects of anoxemia on the brain by the ***synergistic*** action of carbon dioxid excess and oxygen deficiency on the vasomotor center. This action is still present under conditions when the lungs of the animal are artificially ventilated so that spontaneous changes in respiration cannot occur. The increased tonus of the vasomotor center is due to this synergistic action of carbon dioxid and oxygen deficiency. This phenomenon represents an adjustment mechanism which is highly suitable to overcome conditions of insufficient oxygenation of the brain since it is well known that the oxygen supply to this tissue depends primarily on the systolic blood-pressure.

XI. It has been mentioned before that under conditions of anoxemia (experiments in the low-pressure chamber) the temperature falls.[18] In small laboratory animals (mice, rats, and, to a lesser degree, guinea pigs) the fall in temperature may amount to as much as four or five degrees centigrade in twenty to forty minutes. This fall depends only on the decrease in the partial pressure of oxygen.[19] Since the metabolism is greatly dependent on the temperature of the organism, it was thought that this decrease in temperature may represent an adjusting mechanism which allows the animal to survive under conditions of very insufficient oxygenation. This was shown to be true for mice which, in the low-pressure chamber, could tolerate a certain degree of anoxemia without any hazards, provided that the temperature of the surroundings was not artificially elevated. If, however, the temperature in the low-pressure chamber was raised to such a degree that a decrease in the body temperature was largely prevented, most of the animals died. Since the increase in room temperature had no fatal effects in itself, it follows that the lowering of the body temperature during anoxemia represents an extremely effective adjusting mechanism in these animals.[16]

It was then investigated whether the temperature regulating mechanism is affected by the presence of small amounts of carbon dioxid in the inhaled air. These experiments were carried out in the low pressure chamber and the same animal was subjected to several experiments with and without the presence of carbon dioxid. The beneficial effect of carbon dioxid was quite noticeable in the general behavior of the animal. In the absence of carbon dioxid the animal lay on the side frequently, whereas in the presence of carbon dioxid it was able to walk about. The temperature obtained at the end of each anoxemia period showed striking differences. It was regularly lower when carbon dioxid was inhaled at the same time than when it was absent.[20] We have here also, therefore, a synergistic action of carbon dioxid excess and oxygen deficiency as far as the temperature regulating mechanism is concerned.

Although the investigations are far from being complete they indicate that the beneficial effect of carbon dioxid must be explained not only by the increased respiration and prevention of acapnia, but also by the synergistic action which carbon dioxid excess and oxygen deficiency display in regard to the vasomotor center and to the temperature regulating mechanism. As a result, the blood-pressure increase more than corresponds to the effect of each of the two factors, and the temperature of the body is lowered more when carbon dioxid is present. It can be well understood that the beneficial effect of carbon dioxid is due to

both the diminished demands of the tissues for oxygen as a result of the lowered temperature and to the improved oxygenation of the tissue as the result of the stimulation of the vasomotor center.

XII. It is difficult to properly evaluate the importance of the various adjusting mechanisms which are called into play under the conditions which I have studied, but some remarks may be appropriate. We know, for instance, that under the influence of carbon dioxid the oxygen dissociation curve of hemoglobin is altered and that oxygen is delivered more rapidly when carbon dioxid is inhaled than during its absence. This mechanism is obviously not sufficient to explain the complete adjustment observed in our experiments, since, in spite of this change, animals die as a result of anoxemia in the low-pressure chamber at high temperatures, whereas they survive when the temperature of the surroundings is not elevated. Since carbon dioxid and increased temperature have a similar effect on the oxygen dissociation curve, one might expect an even more beneficial effect, as far as the oxygenation of the tissues is concerned, but obviously this mechanism, important as it is, is unable to maintain a sufficient oxygenation of the tissues when the oxygenation of the blood is very deficient and the temperature of the body is not lowered. Then it becomes necessary to reduce the oxygen demand and this is accomplished by the decrease in body temperature.

We encounter here a principle of general importance in the organization of the body. Whenever functions of vital importance are endangered several mechanisms are called into play which tend to remedy the situation. This is obviously the case here. Carbon dioxid alters various structures and mechanisms at the same time, and all these effects tend to improve the oxygenation of the tissues, particularly under conditions of anoxemia.

## SUMMARY

It has been shown that under the influence of oxygen deficiency, hyperpnea and carbon dioxid "psychic" processes are modified in the same manner as other physiologic cortical processes. Moreover, although breathing an oxygen deficient gas mixture produces severe changes in psychic functions (disturbances in association, loss of memory) and slows up considerably the processes involved in simple mental tasks such as the addition of two digits, etc., the addition of 3 percent carbon dioxid restores these functions to normality. A similar statement is true in regard to the effect of 3 percent dioxid in combating the effects of oxygen deficiency on various physiologic functions such as muscular coordination, visual intensity discrimination, galvanic nystagmus, etc. From this it follows that psychic and physiologic processes depend on and are modified by the same fundamental physiologic factors. Psychic processes are not basically different from ordinary physiologic cortical processes. They involve only different degrees of nervous integration. The continuation of this line of investigation, the determination and proper evaluation of the physiologic factors which are necessary for the maintenance of the physiologic activity of the "mind" seems to be of importance to Physiology, Psychology and Psychiatry. The study of the disturbances resulting from the excess or the

deficiency of these fundamental factors will help, it is hoped, to make physiology as indispensable to the understanding of the problems of psychiatry as it is today generally considered to be in regard to the other branches of the medical sciences.

The second part of this investigation dealt with the analysis of the effect of carbon dioxid on anoxemia resulting from breathing oxygen-poor gas mixtures. It was found that the beneficial effect of carbon dioxid is based on:

1. Its stimulatory effect on respiration whereby the alveolar oxygen pressure is raised.
2. The potentiating effect of carbon dioxid and oxygen deficiency on the vasomotor center.
3. The potentiating effect of carbon dioxid and oxygen deficiency on temperature regulation.

It is interesting to point out that the antagonism between oxygen deficiency and carbon dioxid which is very definite in regard to all central nervous reactions studied is based to a large extent on a synergistic action of oxygen deficiency and carbon dioxid excess on the vasomotor center and other physiologic mechanisms. Further, if we take into account that carbon dioxid produces a shift to the right in the oxygen dissociation curve of hemoglobin and that it increases muscular tonus, thereby improving the venous return of the blood to the heart, we realize that the apparently simple fact that carbon dioxid antagonizes anoxemia involves the integration of at least the effects of carbon dioxid on the respiratory and circulatory system, the blood, the striated muscles and the temperature regulating mechanisms. It appears to be a true example of the organism acting as a whole and seems to warrant the emphasis placed in the introduction on what might be called physiology of integration.

## Bibliography

[1] Jordan, H. J. Allgemeine vergleichende Physiologie der Tiere, Berlin and Leipzig, 1929.
[2] Gellhorn, E., and Spiesman, I. Am. J. Physiol., 112, 519, 1935.
[3] Gellhorn, E. Am. J. Physiol., 115, 679, 1936.
[4] Gellhorn, E., and Spiesman, I. Am. J. Physiol., 112, 620, 1935.
[5] Gellhorn, E., and Joslyn, A. Jour. Psychol., 3, 161, 1936.
[6] Gellhorn, E., and Kraines, S. Science, 83, 266, 1936, Arch. of Neurol. and Psychiat., in press.
[7] Gellhorn, E., and Spiesman, I. Am. J. Physiol., 112, 662, 1935.
[8] Gellhorn, E., and Storm, L. Unpublished data.
[9] Cobb, S., and Fremont-Smith, F. Arch. Neurol. and Psychiat., 26, 731, 1931.
[10] Wolff, H., and Lennox, W. Arch. Neurol. and Psychiat., 23, 1097, 1930.
[11] Childs, S., Hamlin, H., and Henderson, Y. Nature, 135, 457, 1935.
[12] Mosso, A. Life of man on the high Alps, London, 1898.
[13] Gellhorn, E. Am. J. Physiol., 117, 75, 1936.
[14] Gellhorn, E. Nature, 137, 700, 1936.
[15] Gellhorn, E., and Ury, B. Unpublished data.
[16] Gellhorn, E. Ann. Int. Med., 10, 1267, 1937.
[17] Lambert, E. H., and Gellhorn, E. Proc. Soc. Exp. Biol. & Med., 36, 169, 1937.
[18] Behague, P., Garsaux, and Richet, C. Compt. rend. Soc. biol., 96, 766, 1927.
[19] Gellhorn, E., and Janus, A. Am. J. Physiol., 116, 327, 1936.
[20] Gellhorn, E. Am. J. Physiol., 120, 190, 1937.

# THE INVINCIBLE URGE TO KNOW*

Frank J. Studer

A manufacturing company recently was faced with the following problem: There had been developed for the process of casting certain important tools, an alloy of zinc which far surpassed any material previously employed, and this alloy was coming into wide use. Every now and then, however, there would come through a batch which had apparently been made according to specifications and which appeared perfectly satisfactory, but which, when put into service, would become brittle and crumble. The problem was to find what conditions of manufacture gave rise to the bad product, or in any case, to devise a method of testing, so that an inferior batch could be spotted and discarded before it was put into use.

A long and costly study showed that the crumbling of the alloy was due to the presence of minute quantities of certain elements, quantities so small that they were apt to occur even in rather highly purified zinc. To summarize briefly, it was found that any of the metals, magnesium, copper, iron, lead, tin, cadmium, present to more than five parts in 100,000 would render the alloy useless.

With the cause discovered, it was still another matter to tell whether any of these elements was present in an excessive amount or not. Ordinary chemical methods were not entirely impossible, but they were prohibitively slow and expensive.

The method that was resorted to is known by the name of "spectroscopic analysis." A small sample of the alloy is placed in an electric arc or spark, its molecules are there automatically dissociated into their constituent atoms, and these are stimulated by the electric current to emit light. This light is sent through a spectrograph which analyzes it into its component colors or wave lengths, recording them as spectrum lines on a photographic plate. From this photographic plate, after it has been developed, an experienced observer can tell at a glance whether the sample is good or useless. Each element in the alloy gives out its characteristic colors in the electric arc, and the brightness of these various colors, as indicated by the amount of darkening of the photographic plate, give an indication of the abundance of the element to which it is due. The whole process may consume fifteen minutes or less, and then it is known with certainty whether the batch of alloy is usable or not.

There are many interesting things that could be told about the methods and applications of spectroscopic analysis. I have used this topic mainly, however, to lead up to quite a different line of thought. The method of spectroscopic analysis came as one of the valuable bits of driftwood that was borne with many others on a great flood of advancing knowledge in the field of optics—a flood loosed, not, as often seems to be the case, by the tremendous genius of one man,

* Address before the students of Union College, May 20, 1937.

but rather by three men, thinking quite independently on similar problems. It is to something about these three men that I wish to call your attention.

I take it we are all looking for a simple formula—trying to find some easy things to multiply together on the left-hand side of an equation to get something on the other side that we call achievement. By achievement we may mean different things; it may be at building bridges, or smashing atoms, or at writing newspaper columns, or even at driving home a truth or two into undergraduate heads, but we would all like to chalk up something that will win other people's respect after we have had our trial.

Well, here I thought I had a good place to look. Here were three men, all of whom did achieve something. After the searching judgment of a century, we place their names among the greatest of all times in their chosen fields. They lived at the same time, they had the same field of endeavor. In other words, as the psychologists might say, they were well-controlled subjects. When I did look, I found their stories so interesting that I thought I would tell you a little about them, and hope that you would read more.

Needless to say, a formula was not found. But many of the factors that are usually thought to be essential are not there at all. A brief story about these men will reveal this.

The three men are Thomas Young, Jean Fresnel, and Josef Fraunhofer. The great advance in the field of optics to which I have referred has to do with the reversion in the point of view taken toward the nature of light, specifically the acceptance and development of the idea that light has the characteristics of a wave motion. It was Young who first clearly saw the possibilities of this point of view for dealing with the so-called "interference phenomena." It was he who loosened the foundation of the dam where the flood started.

Thomas Young seemed to be the most favored of the three as far as opportunity is concerned. He was born in England of well-to-do parents. He was extremely bright as a child. He could read at the age of two. When four years old he is said to have read the Bible through. He had access to books, classical, scientific, or literary, and despite the fact that he spent a great deal of his time reading, he managed to grow up without hurting his physical and intellectual powers. He studied medicine, and began practice in London, but was never very successful at it. All his life he was financially independent, and was free to give his time fully to whatever pursuit he might choose.

It is interesting to notice that the established scientists of his time saw little of value in Young's ideas. In fact, one of them, writing in the *Edinburgh Review,* protested vigorously "against innovations that can have no other effect than to check the progress of science." Young issued an able reply to the attacks against his theory, and published it in the form of a pamphlet, but it failed to turn public opinion in favor of his ideas, because, he said, one copy only was sold.

It was Fresnel who saw the possibilities in Young's theory and made a very effective study of its implications, and presented them so clearly and convincingly that his critics had to back down. Jean Fresnel was born in France. Things did not look as bright for him as for Young. He advanced very slowly at his studies, being, at eight, scarcely able to read. The state of his health was always delicate. In fact, he gave little promise, as a boy, of ever amount-

ing to anything. He did go to college, taking an engineering course. Then he went to work as a road engineer. All of his experiments and studies were carried on at the same time that he was making his livelihood supervising road making or similar work. Yet the number of pages of good sound optical theory that came from his pen is simply enormous.

The experimental check on the ideas of Young and Fresnel required carefully made optical apparatus, and it was Josef Fraunhofer who devised methods for manufacturing it. To him also is due the entirely new tool, the defraction grating, upon which the method of spectrographic analysis depends. Fraunhofer, as a boy, didn't seem to have a chance. He was born the eleventh child of a poor glassmaker in Germany. An orphan at an early age, he was apprenticed to a glass polisher and mirror maker in Munich, where he had also to be of service in the house and kitchen, being bound for six years, since he could pay no premium for his apprenticeship. He had no opportunity for attending school. However, in spite of these handicaps, and in spite of the fact that, like Fresnel, was never free from routine duties, he had an incalculable influence on the advance of optical practice.

Now, in spite of what you may suspicion, I have not tried to draw a moral. I have merely thought that I would call to your attention these three men of a century ago, who achieved so much that we still esteem, yet whose opportunities for achievement seem to have been so entirely different. I would recommend that you read their biographies—an Englishman, a Frenchman, a German; one brilliant at learning from books, one who struggled hard for all he learned in school, and one who had no chance at school; one rich, another of limited means, and the last extremely poor. There's no easy formula there! They had this in common—each of them found an intellectual pursuit outside his routine occupation which was to him fascinating enough to work at for no other reason than the sheer fun of doing it.

# IN MEMORIAM

## WILLIAM FOSTER

The Princeton Chapter of the Society of Sigma Xi records with sorrow the death on May 24, 1937, of William Foster, Russell Wellman Moore Professor of Chemistry in Princeton University.

Born at Hartford, Kentucky, May 15, 1869, he received the degrees of Bachelor of Arts from Hartford College in 1892 and Bachelor of Science from Vanderbilt University in 1893. After teaching science for two years at Hartford, he came to Princeton University for graduate work, receiving the degrees of Master of Arts in 1896 and Doctor of Philosophy in 1899. At Princeton he served as assistant in chemistry from 1896 to 1898, returning to Kentucky to serve as professor at Central University from 1899 to 1900. In 1900 he began a period of thirty-seven years of continuous service to Princeton University, five years as instructor, five as assistant professor and the remainder as professor of chemistry. In 1933 he succeeded the late Professor McCay, retired, in the Russell Wellman Moore Chair of Chemistry.

Professor Foster's earlier interests in investigation were partly in the same fields as those of his colleagues, McCay and Neher, with whom occasionally he collaborated in publication. In his later years, he developed a strong interest in the application of chemistry to archæology and, as chemist for the American Excavations at Corinth and Athens, he studied the composition of coins, stucco, pigments, and especially the glazes of ancient Greek pottery, a subject to which he had already given attention as early as 1910. In the historical and biographical fields, his various articles on Dr. John Maclean, professor of chemistry at Princeton, 1795, and on Doctor McCay added to the lustre of his predecessors. On the formation of the Princeton Chapter of Sigma Xi he became one of our charter members.

Professor Foster's keenest interest was in the teaching of chemistry. He was a contributing editor of the *Journal of Chemical Education* and a member of the "Senate of Chemical Education" of the American Chemical Society. For many years he acted as chief examiner in chemistry for the College Entrance Examination Board. He was the author of several widely used textbooks and manuals for schools and for colleges, written with the logic and clarity of his lectures, and of a semi-popular book, written for the layman, "The Romance of Chemistry," which appeared also in German translation as "Welt und Wunder der Chemie." As an associate editor, he contributed articles on chemical subjects to *The New International Year Book* and to *The Chemist.*

He will be remembered with affection by several thousands of Princeton undergraduates over a period of thirty-nine years. To these he was kindly as well as just, inspiring confidence by his own high integrity. In his unswerving devotion to duty, he was a shining example to students and colleagues alike. He served his community in many ways, including sixteen years of service as an elder in the Presbyterian Church.

At the end of the last academic year, Professor Foster, had he lived, would have entered upon a well-earned period of retirement from active duties. With his passing, the Princeton Chapter of Sigma Xi has lost from its numbers a trusted colleague, a devoted teacher and a loyal friend.

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## SIGMA XI EMBLEMS

All insignia of the Society are available only through the office of the National Secretary. They are made in various styles and sizes, and in white and yellow gold. Orders for these insignia are issued through chapter secretaries, and must be *prepaid*. Information about styles and prices may be obtained from chapter secretaries or the National Secretary.

## DIPLOMAS FOR MEMBERS AND ASSOCIATES

These diplomas are available in any quantity at 10 cents each. Orders should be sent to the National Secretary, should specify whether for members or associates, and should be accompanied by check.

## INDEX CARDS

Index cards for newly elected members and associates are available *gratis* upon requisition from chapter secretaries to the National Secretary. These cards should be made out in duplicate, one set being retained for chapter files and one set being sent to the National Secretary for filing in the permanent records of the national organization.

## NATIONAL CONSTITUTION

Printed copies of the National Constitution, containing all amendments to date, and all recent interpretations as made by the national officers on request of chapters, are available at 9 cents each from the National Secretary.

## CHANGES OF ADDRESSES

Chapter secretaries are asked to send to the National Secretary in October of each year changes in their enrollment lists as follows: 1. Names and addresses to be deleted from the previous list; 2. Names and addresses to be added to previous list; 3. Changes of addresses of those on previous list who may have moved to a new address since the list was submitted.

## SIGMA XI STATIONERY

Stationery in the official color of the Society is now available for all chapters and clubs at $1 per 100 sheets and $1 per 100 envelopes. The letter sheets bear the Society's seal embossed in white but no printing. The envelopes are the official square envelopes used by the national officers. Printed heading on the sheets and printed corner cards on the envelopes can be provided at cost, when so desired.

EDWARD ELLERY,
*National Secretary,* Sigma Xi,
Union College,
Schenectady, N. Y.